LEVERHULME

Centre for **Wildfires, Environment** and **Society**

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Human-Earth system interactions in JULES: Landscape fire

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Collaborators:
Matt Kasoar & Apostolos Voulgarakis (modelling)
Cathy Smith & Jay Mistry (literature meta-analysis)
Sarah Matej, Karl-Heinz Erb (model evaluation)
LandSyMM consortium (human capital SSP projections)
Joanne Hall (Crop fire evaluation & projections)

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Contents

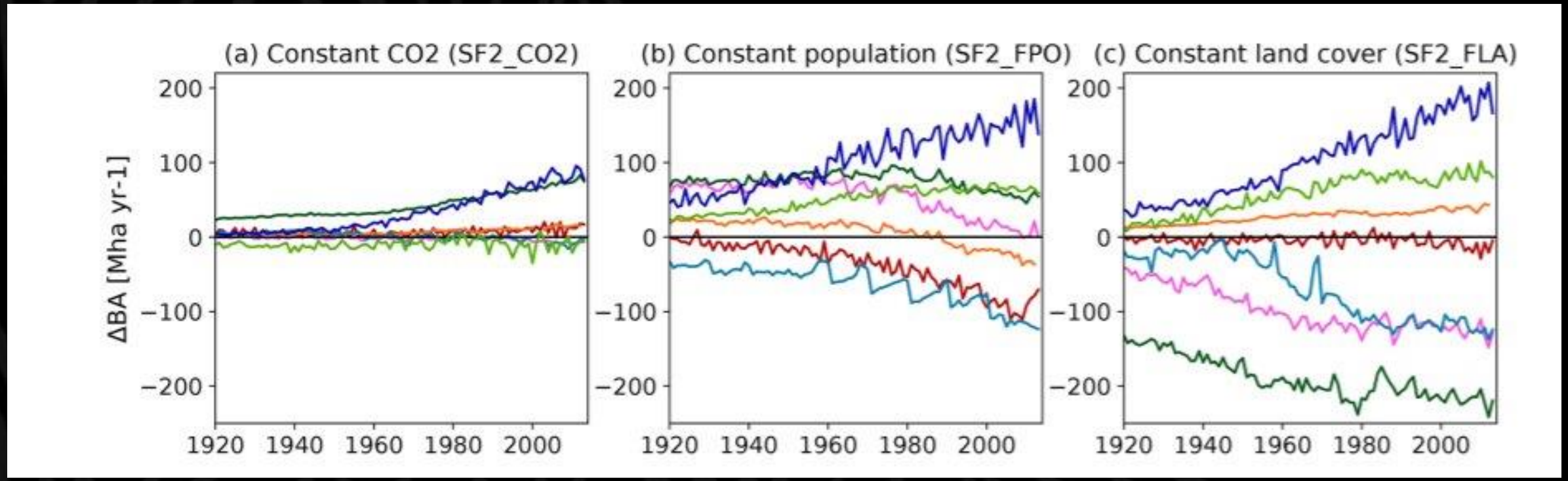
- We have built WHAM! – the Wildfire Human Agency Model
  - Motivation
  - Method

- We have (loosely) coupled WHAM! with JULES-INFERNO
  - Improved quantitative benchmarks for JULES-INFERNO model
  - Improved understanding of underlying processes

- What's next?
  - Online coupling & emissions
  - *What other systems could we address in this way?*

Our starting point: results from FIREMIP

- The Fire Model Intercomparison Project found **anthropogenic impacts on fire were the central causes of disagreement** amongst models, and between models and observations.

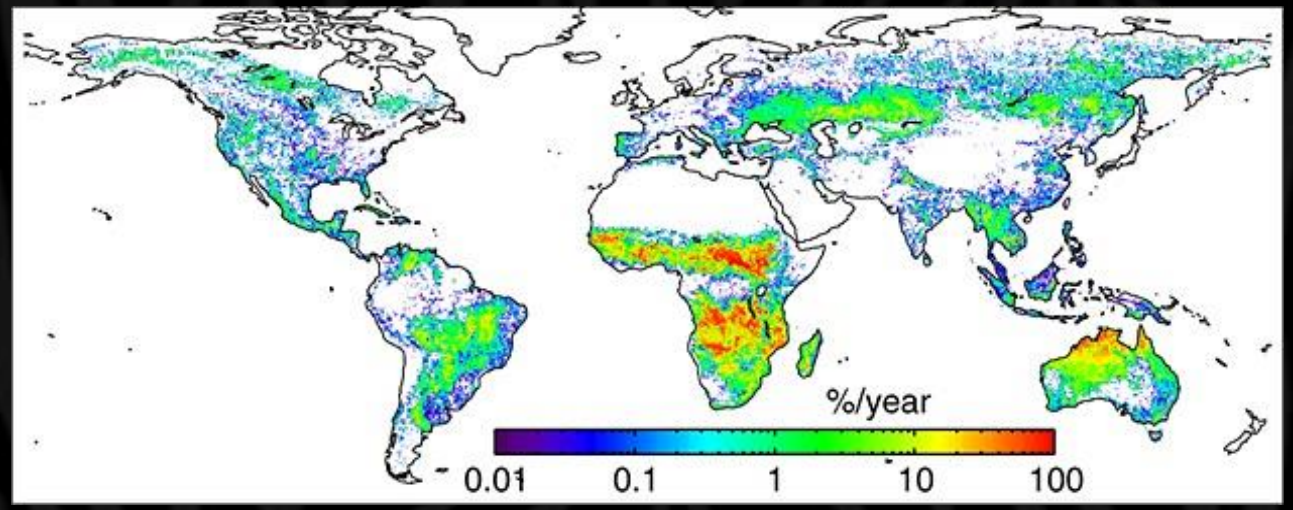


From Teckentrup *et al.* (2019) - Counterfactual scenarios assessing FIREMIP model ensemble sensitivity to atmospheric CO_2, human population and land cover (INFERNO in Orange)

Remote sensing burned area has doubled…

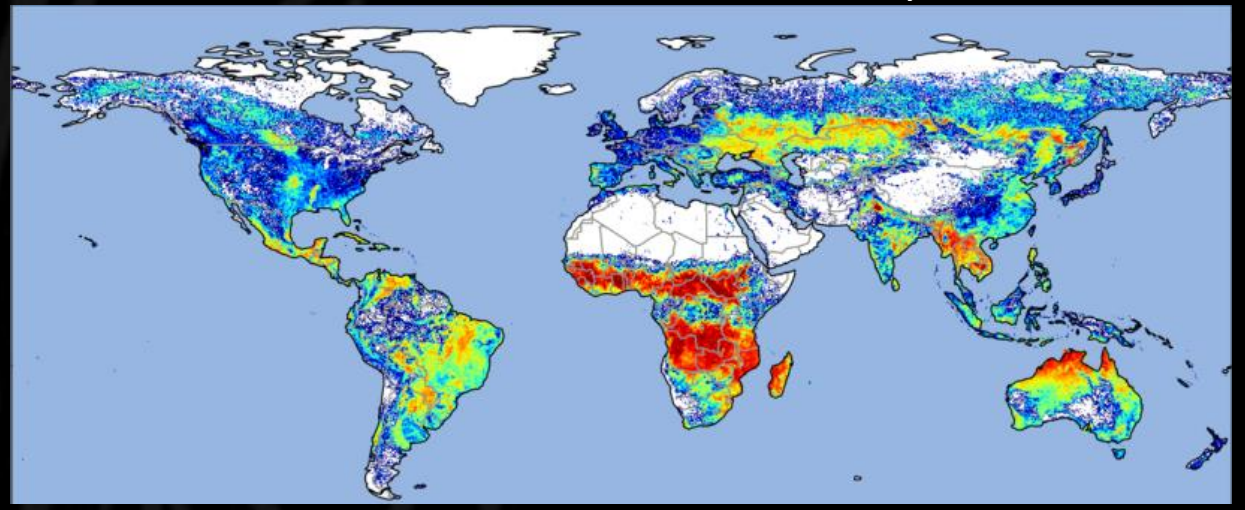
- *Fine-scale remote sensing means global products project 133% more burned area than was previously detectable*

GFED v4: no small fires, 343Mha burned area yr^{-1}



Giglio et al., 2013

GFED v5: no small fires, 800Mha burned area yr^{-1}



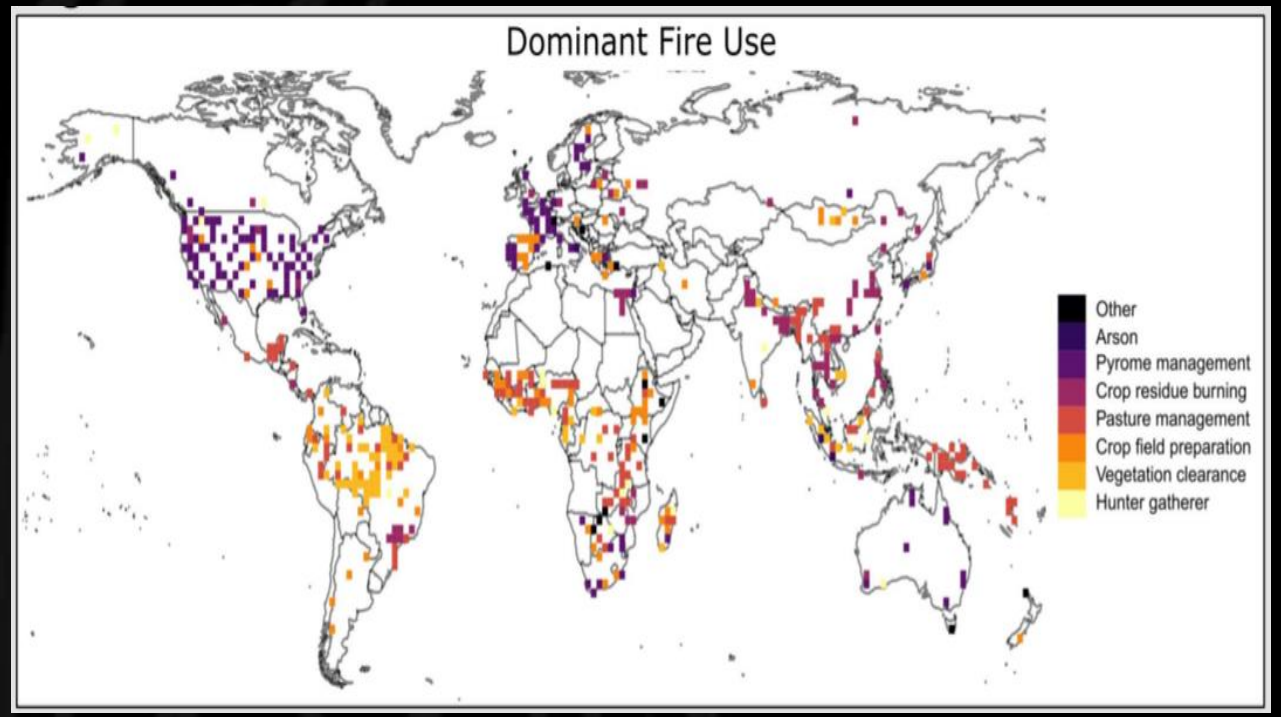
Chen et al., (in review)

Empirical parameterisation: DAFI

- Meta-analysis of human fire literature, spanning 1809 case studies in 504 papers

Fire Use	Median Size (ha)	Mean Burned Area (% LS)	Escaped (%)
Crop Field Preparation	0.7	14.2	0.05
Crop Residue Burning	3.6	36.3	0.01
Pasture Management	10.7	32.1	4.97
Hunter-Gatherer	1.3	14.3	2.90
Pyrome Management	40.8	14.0	0.30
Vegetation Clearing	4.7	2.5	3.23
Arson	N/A	N/A	N/A

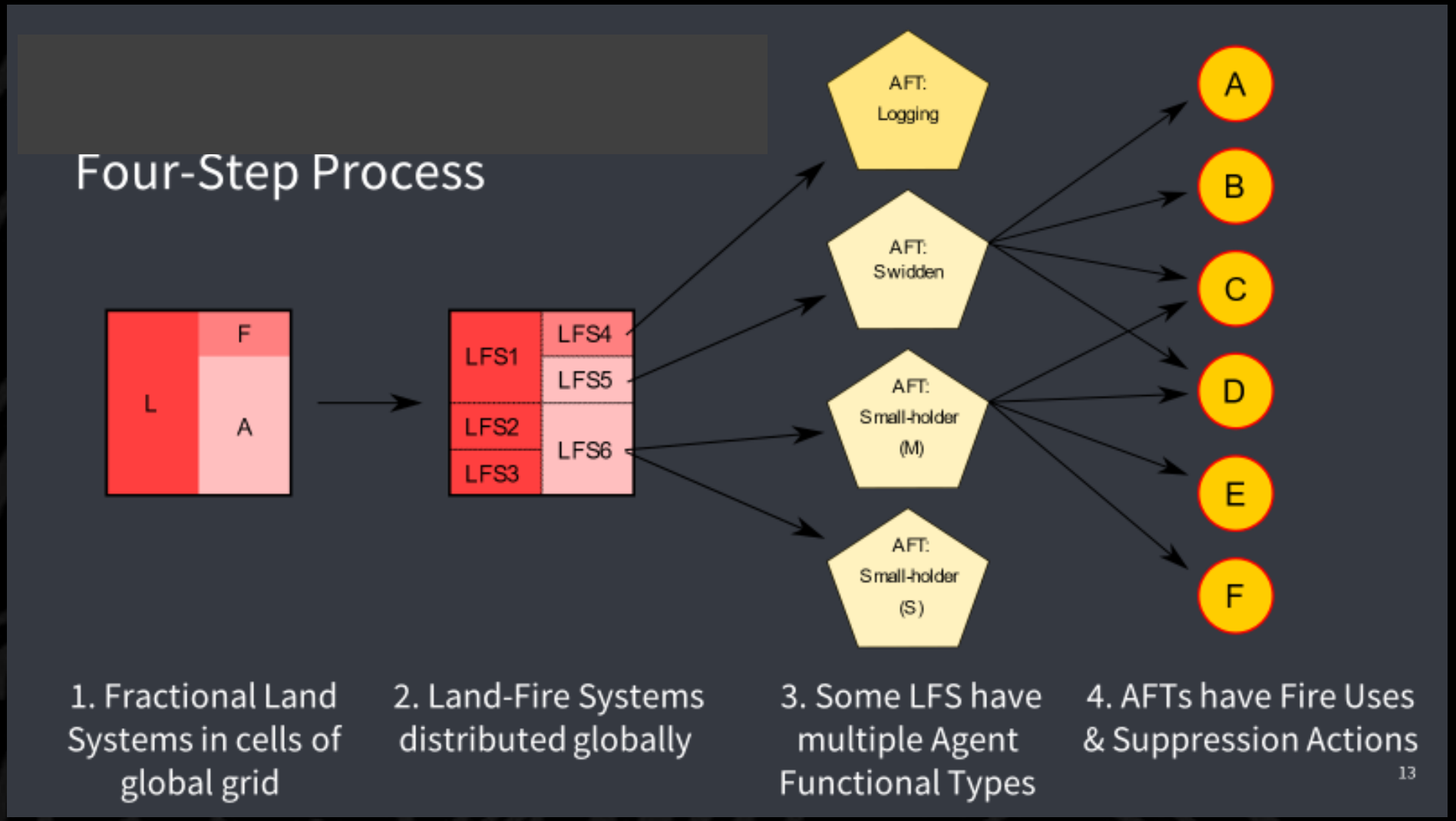
Distribution of fire uses (dominant) in DAFI data



Get the data! - doi.org/10.3390/fire5040087

Millington et al., 2022

How does WHAM! work?

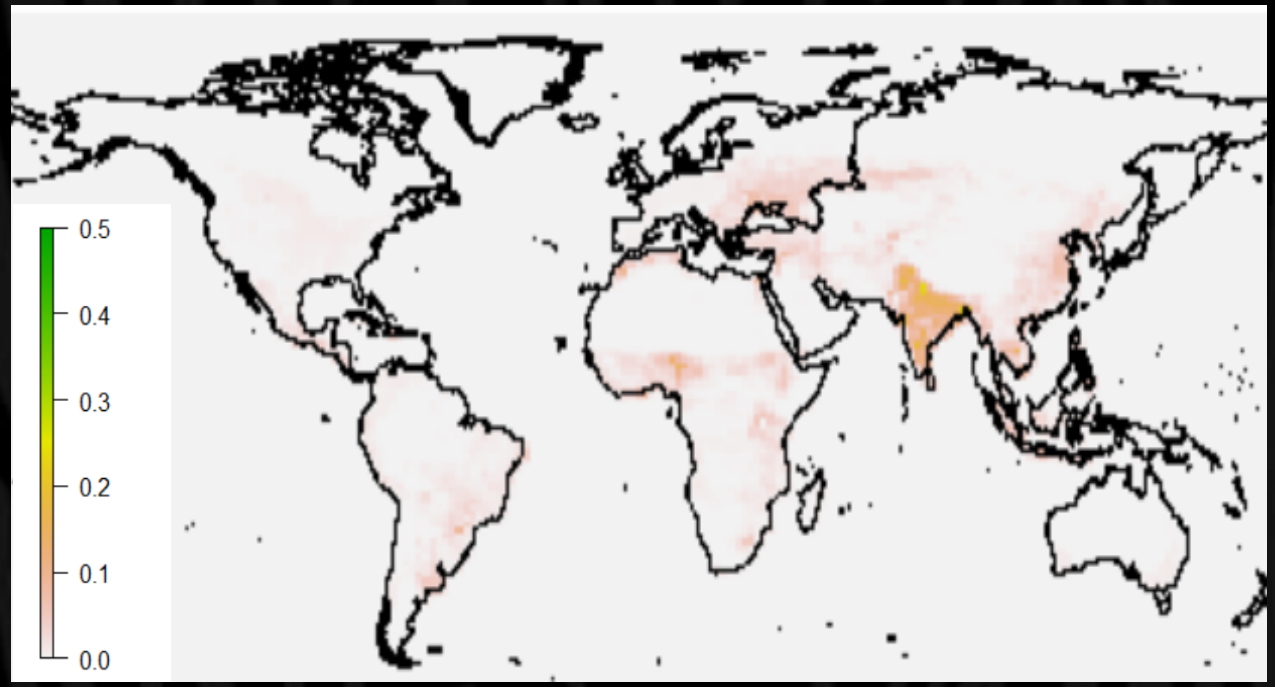


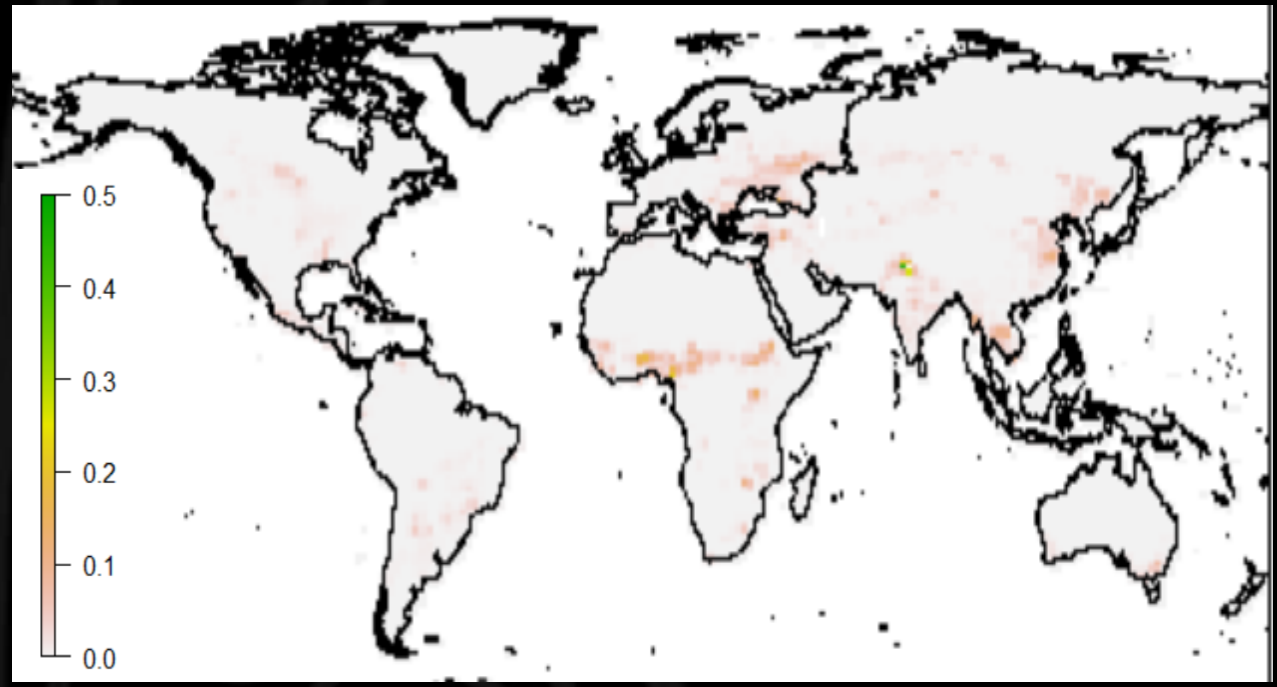
Perkins, O., Matej, S., Erb, K.-H., & Millington, J. (2022). doi:10.18174/sesmo.18130

Millington et al., 2021, EGU

WHAM!: Managed fire outputs

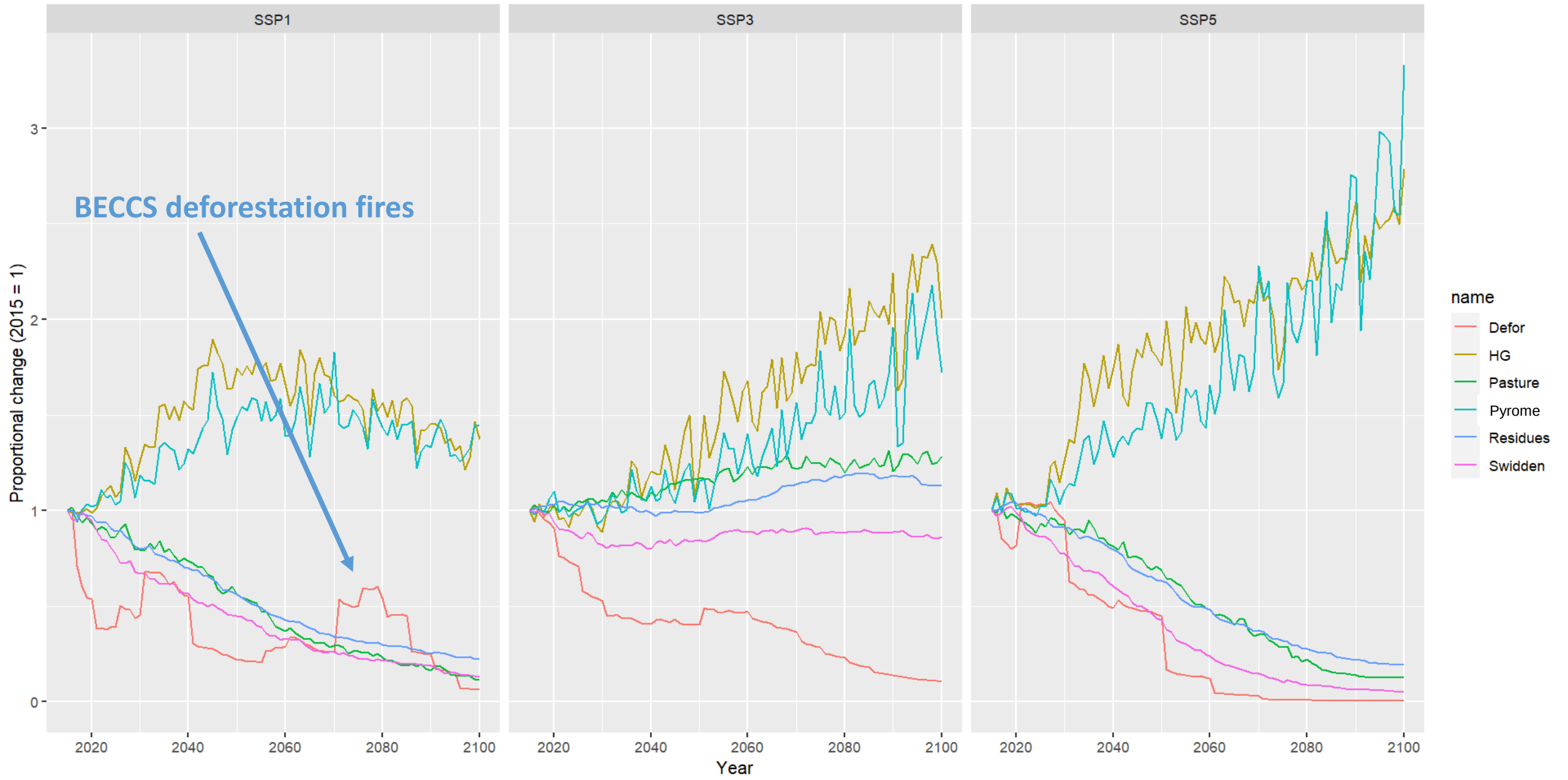
- Evaluation of full model outputs require coupling with INFERNO fire model
- Here we compare crop fire outputs with GFED5 crop fires: **r=0.70**





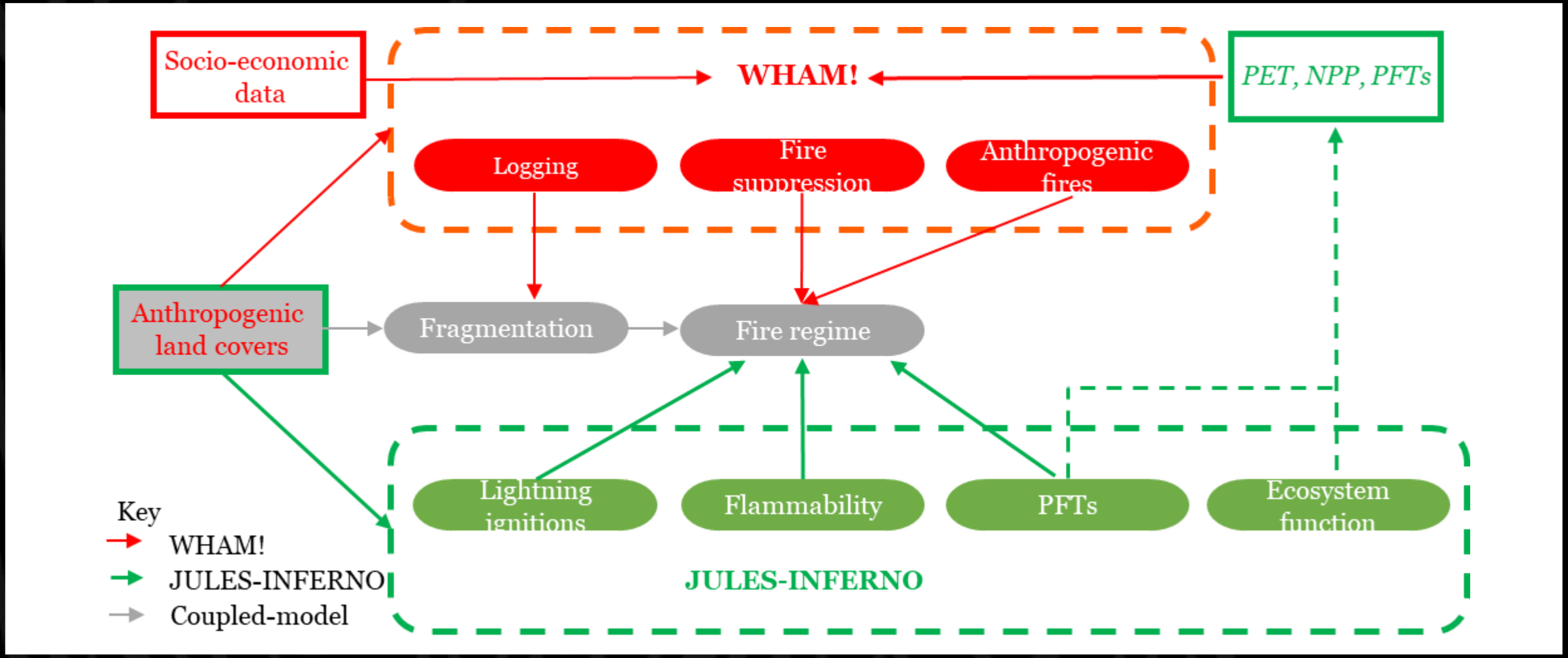
Perkins et al., (in submission), *GMD*

WHAM! SSP runs (proportional change)



A coupled model: WHAM-INFERNO

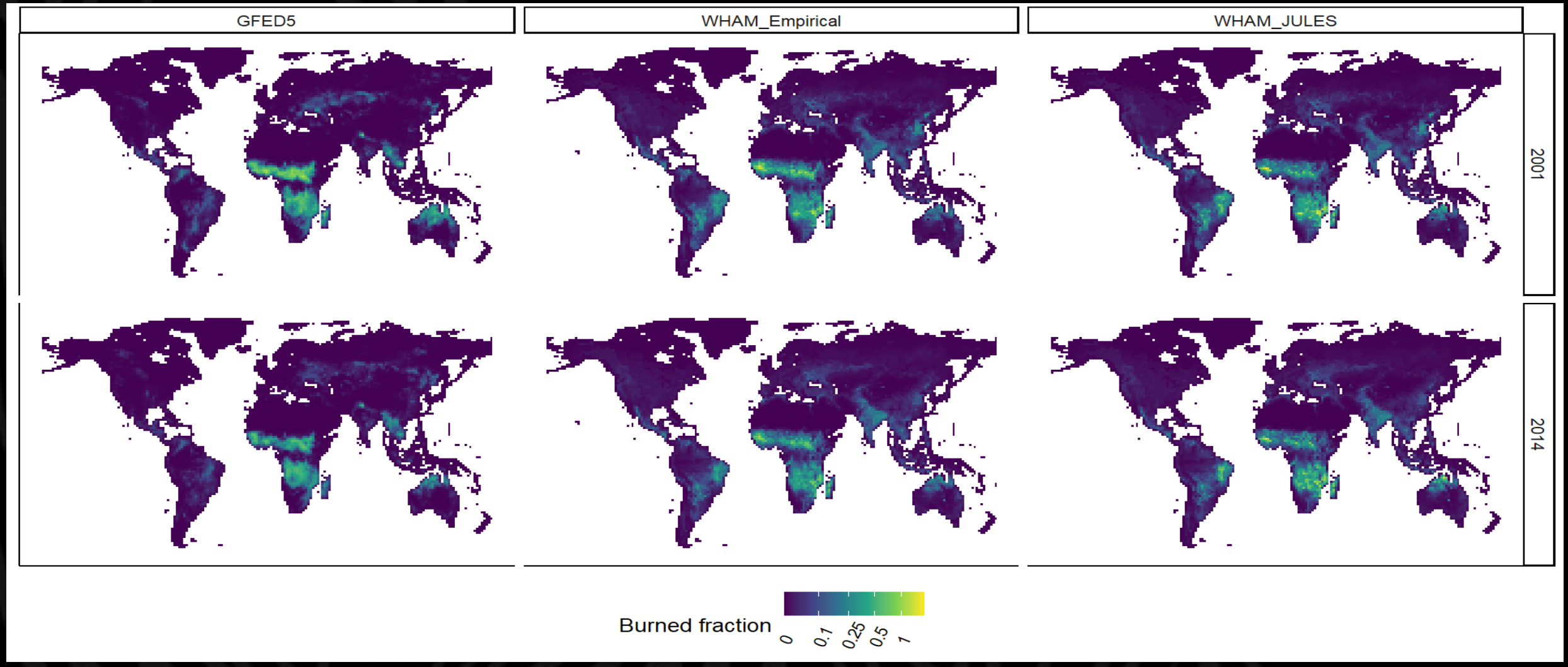
WHAM-INFERNO combined model



With Kasoar & Voulgarakis (in prep)

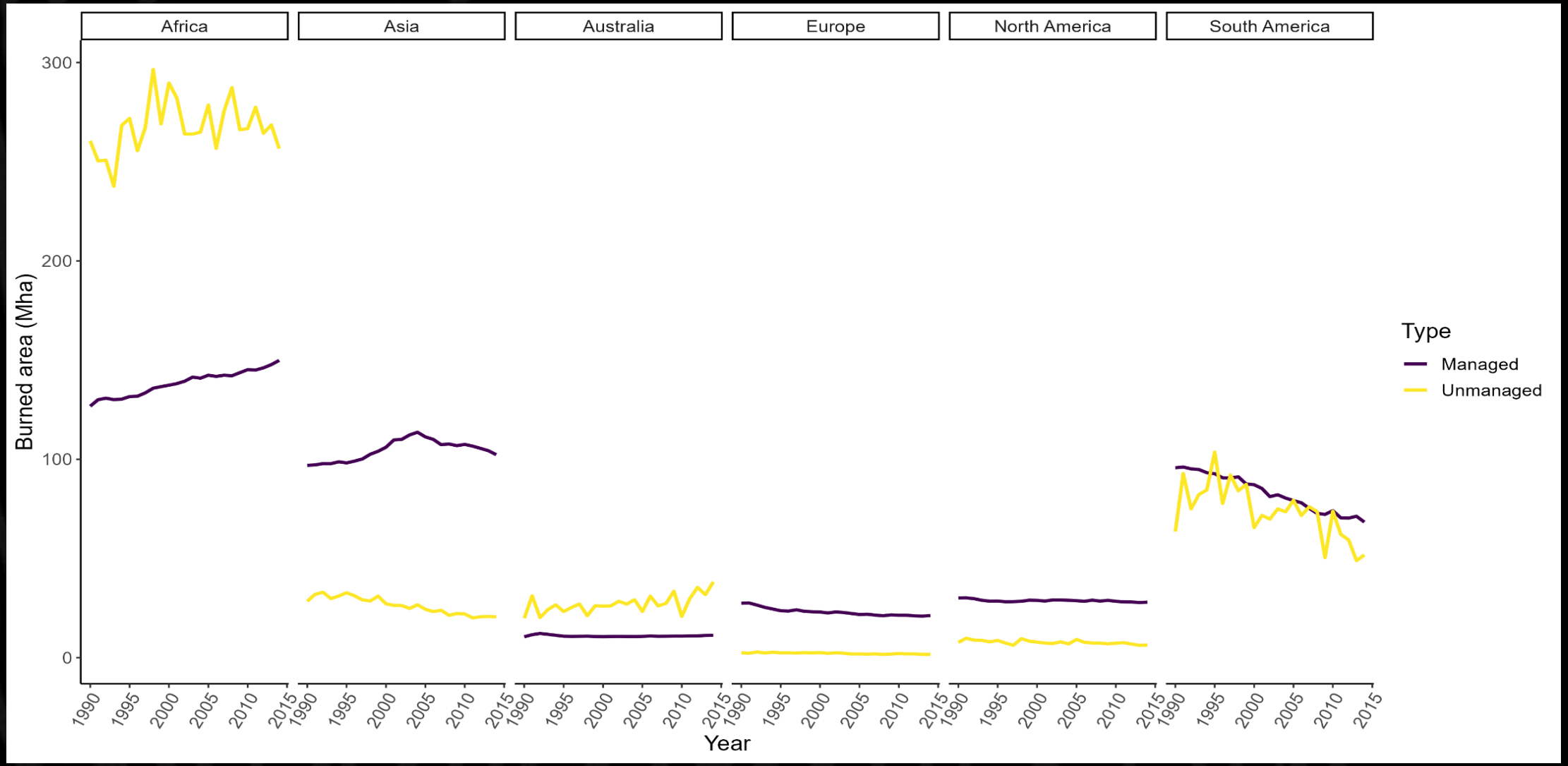
WHAM-INFERNO improves performance

- 10k runs sampling uncertain parameter spaces of WHAM-INFERNO & INFERNO (offline)
- WHAM-INFERNO (r=0.734, empirical r=0.791) significantly improves (Ztest; $p<2.2e^{-16}$) INFERNO (r = 0.584)



Managed & unmanaged fires

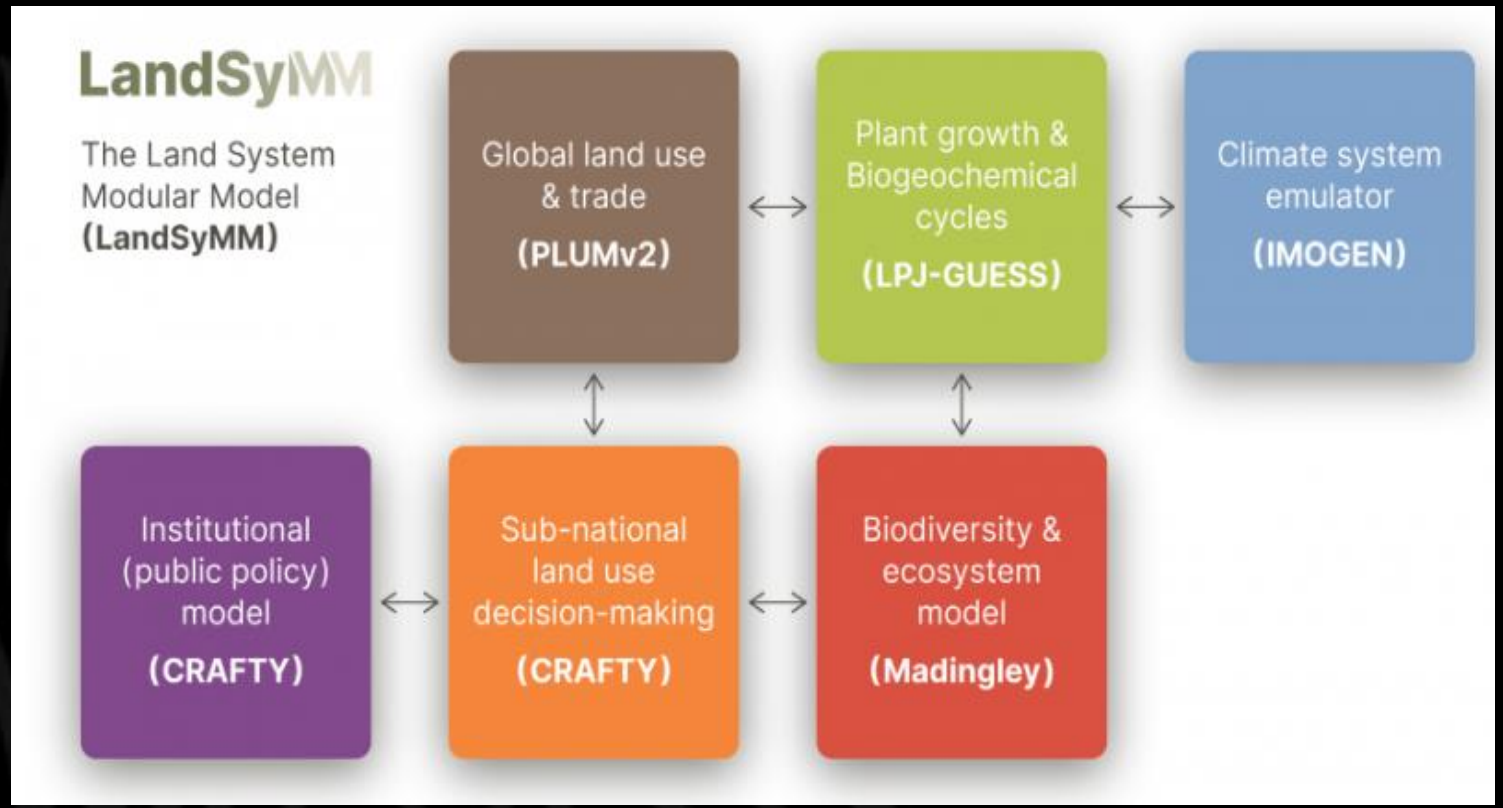
- **Contributions of managed fire, and its temporal trend varies hugely by continent**



Further opportunities for large-scale ABM in JULES?

- Future research could include:
  - Tree planting, negative emissions' markets & fire
  - Biodiversity, nitrogen & food security
  - Water use & climate adaptation

LandSyMM (Arneth, Alexander, Rounsevell) is the most advanced land system simulation modelling framework; it is based around LPJ-GUESS



landsymm.earth

One Earth

CellPress

Perspective

Quantifying the feasible potential of land-based carbon dioxide removal

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Next steps

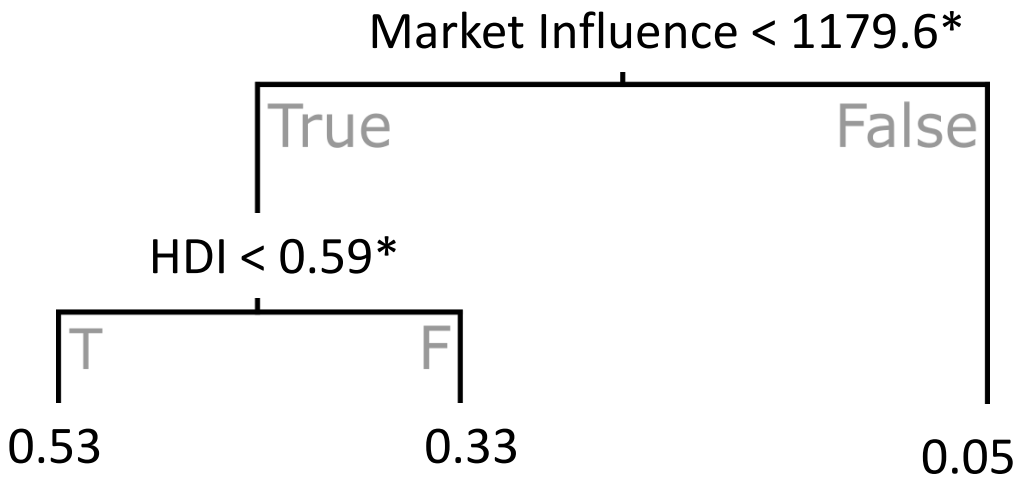
- Tight (online) coupling with INFERNO paused pending re-calibration of tree resprouting: *doubling the amount of fire has implications for vegetation…*
- After ISIMIP future runs, we can run the offline ensemble for the SSPs
- WHAM! standalone can make crop fire emissions' calculations & projections
- Scoping of additional opportunities for human-Earth system modelling with JULES!

Appendices

WHAM! land use engine

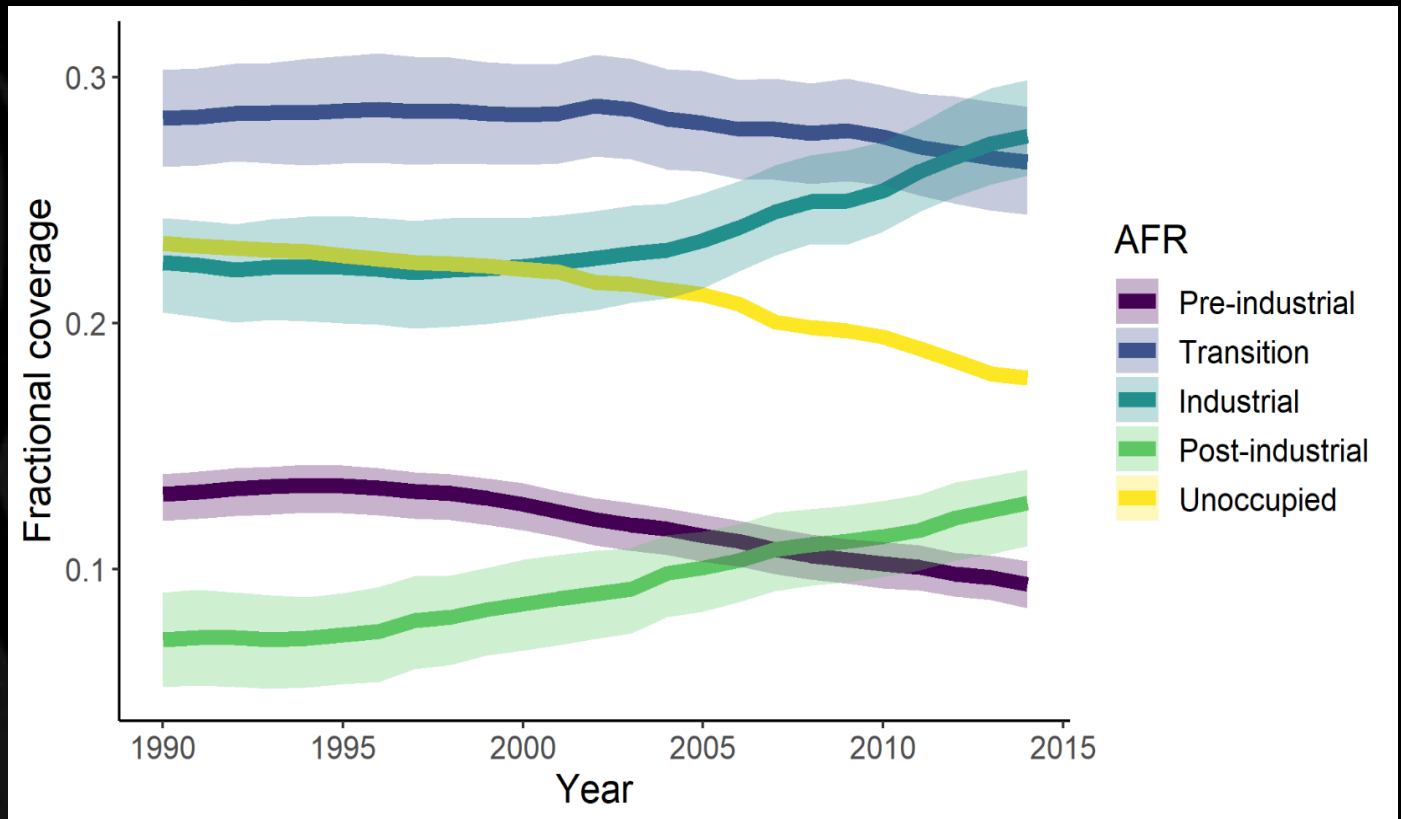
- Empirically-based distribution function: 1 tree per AFT, outputs for AFTs within each land system compared

Example distribution tree: Swidden



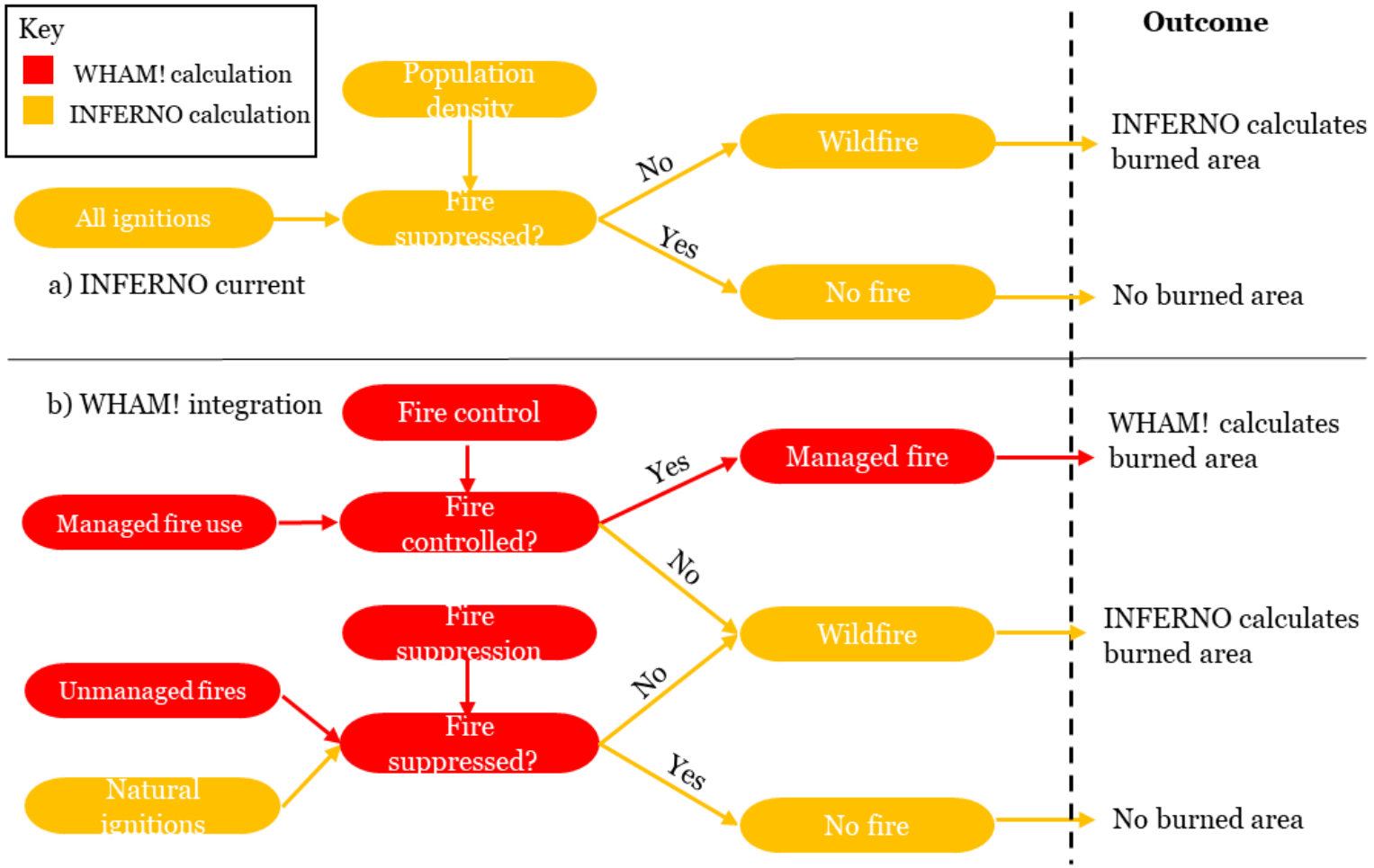
*Fuzzy thresholds from bootstrapping

Global land-surface coverage of Anthropogenic fire regimes



Perkins, O., Matej, S., Erb, K.-H., & Millington, J. (2022). doi:10.18174/sesmo.18130

Changes to INFERNO processes

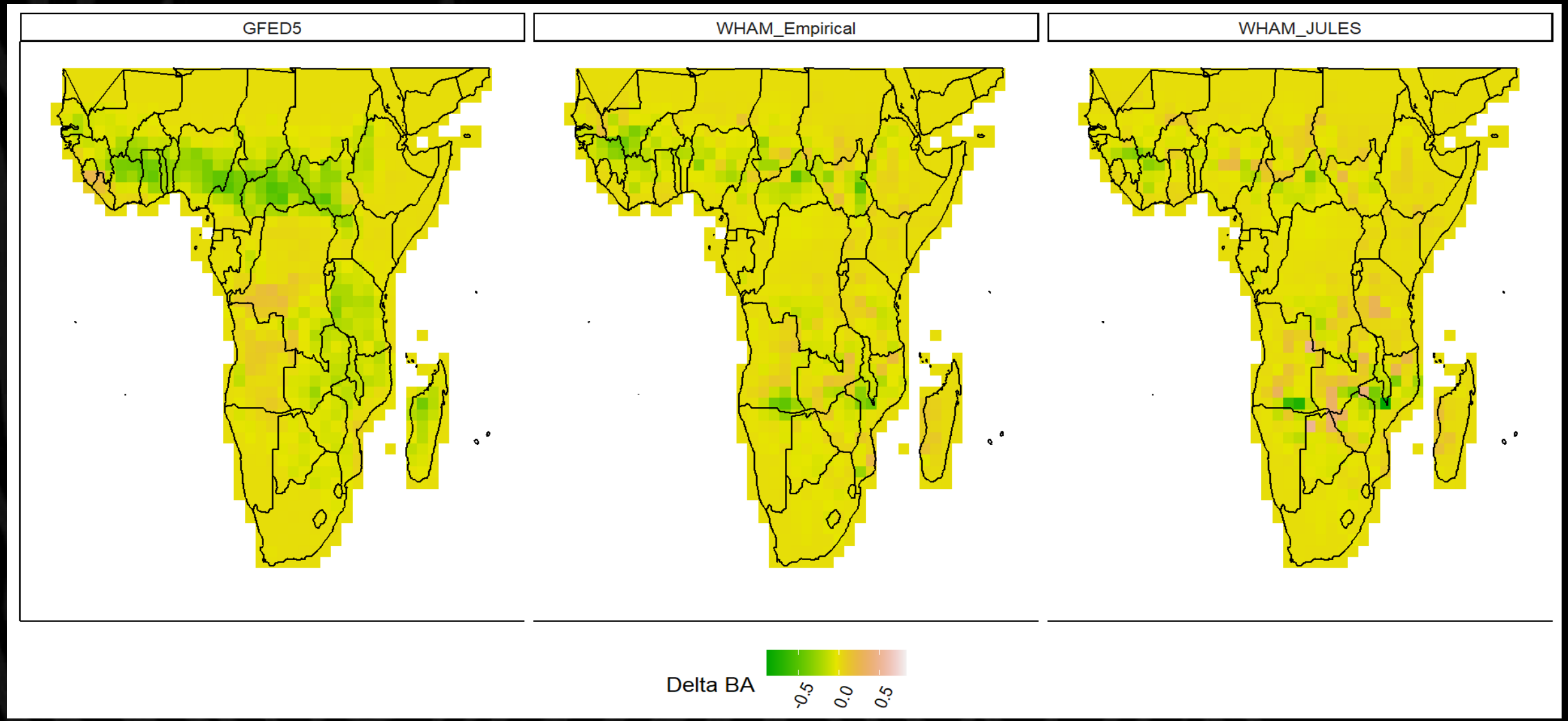


Declining fire in SSA (2001-2014): capturing fragmentation effects?

Delta BA (SSA): -111.8Mha

Delta BA (SSA): -57.9Mha

Delta BA (SSA): -13.5Mha

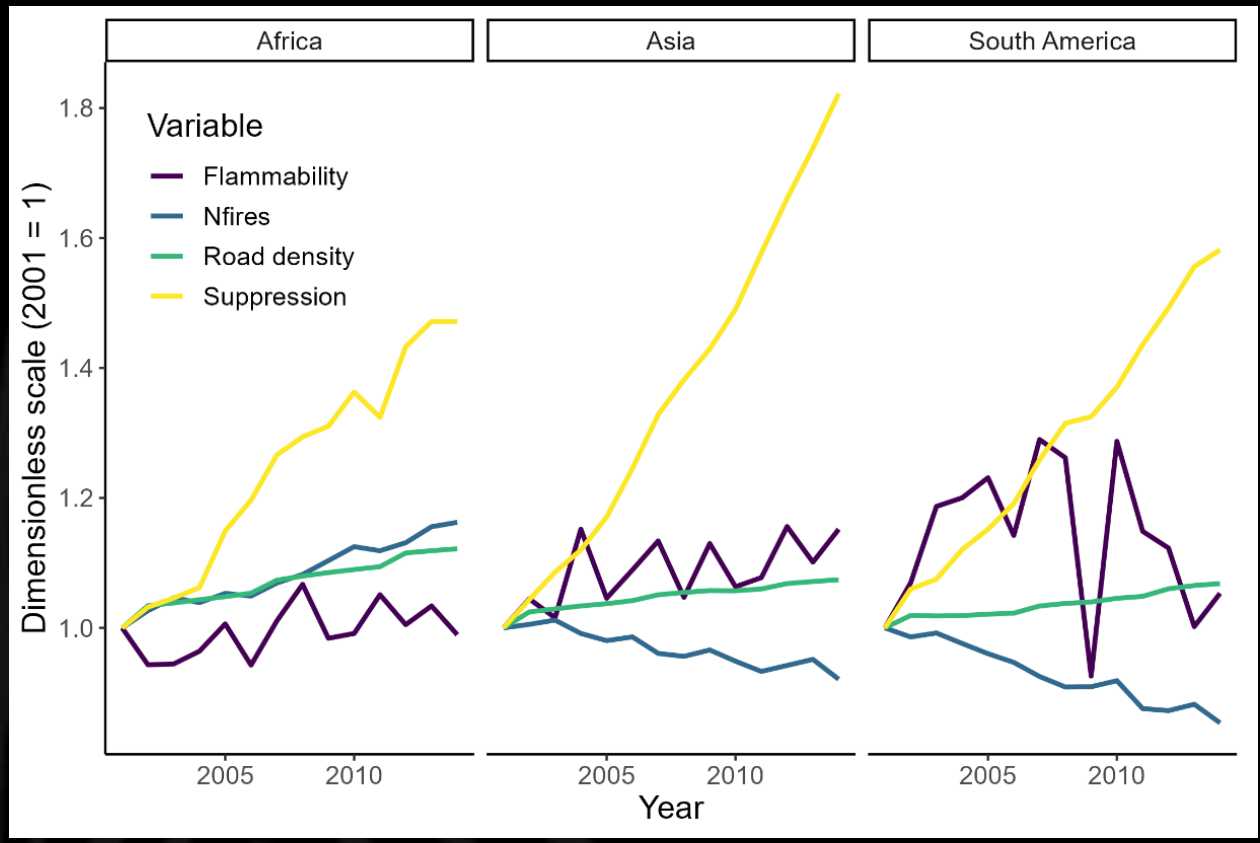


Drivers of unmanaged fires: WHAM_JULES-INFERNO

Right: Dependent variables of unmanaged fire (2001=1)

Below: Correlation (r) of WHAM-INFERNO unmanaged fire with its dependent variables

Continent	Flammability	Number of fires	Road density	Suppression
Africa	**0.80**	0.18	0.12	0.13
Asia	-0.28	-0.17	**-0.95**	**-0.91**
South America	**0.50**	**0.70**	**-0.68**	**-0.68**

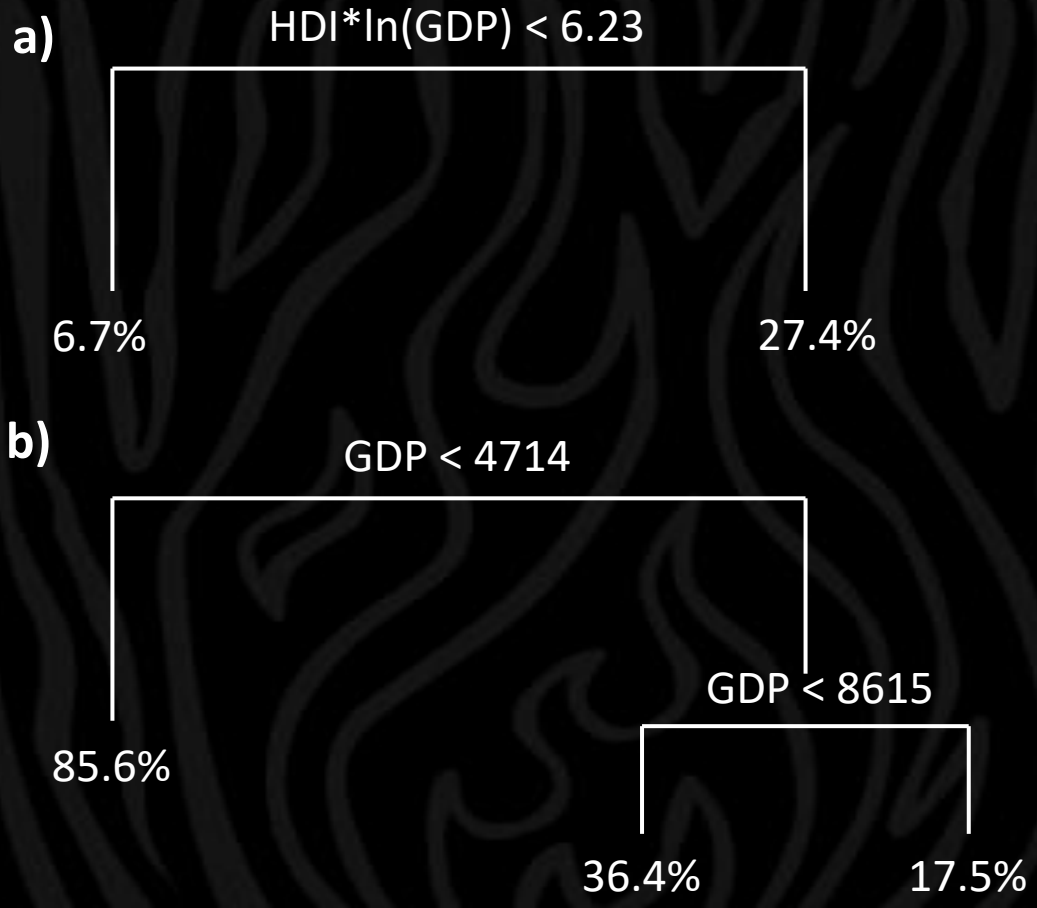


What's driving the error in India?

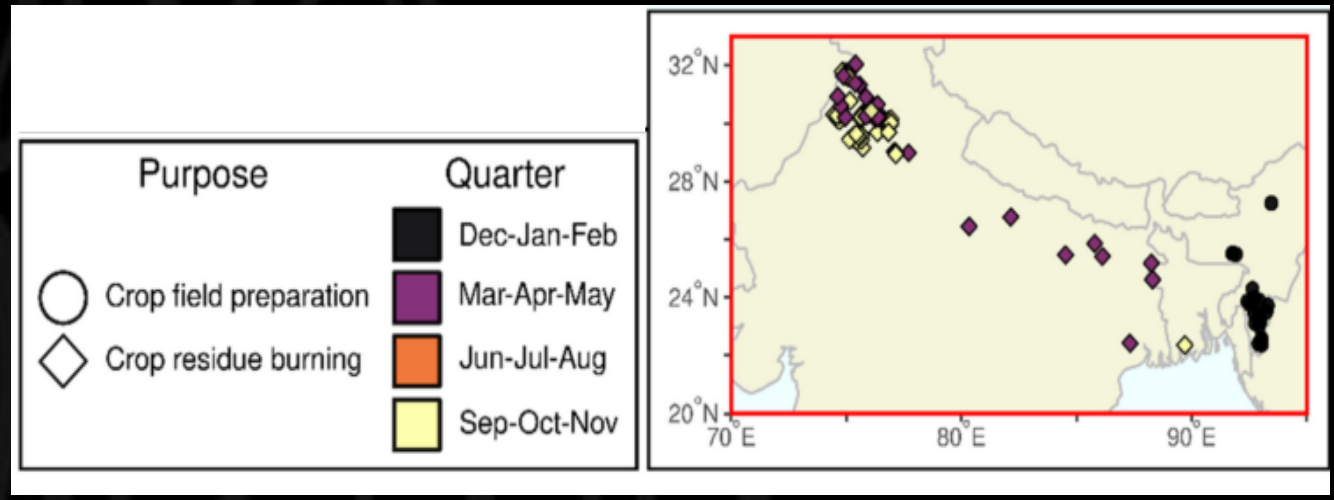
Crop residue burning (% area occupied) for:

a) Subsistence-oriented smallholder

b) Market-oriented smallholder



- **Regression to mean in WHAM?**
- **Seasonality issues with remote sensing?**
- **A bit of both?**

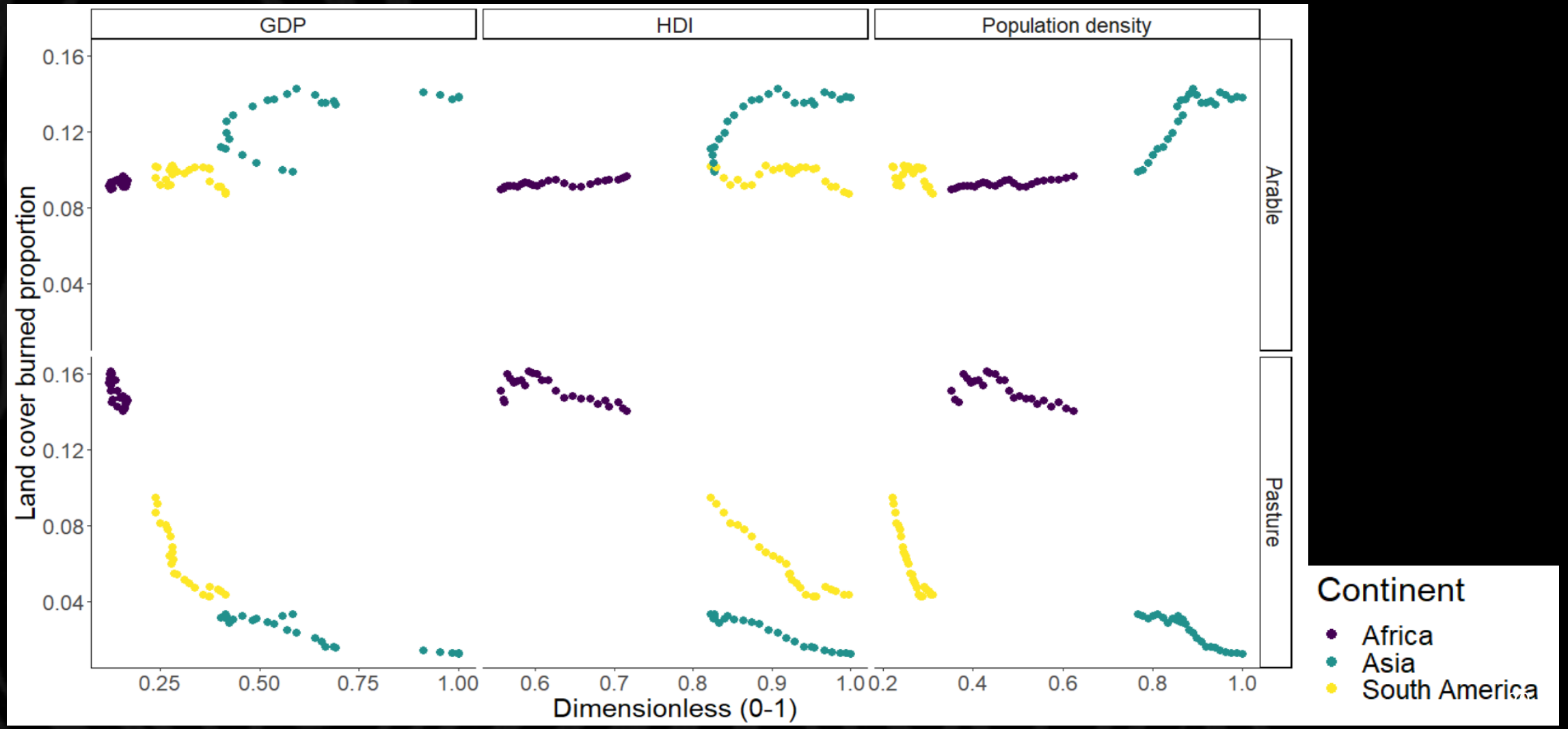


Underlying DAFI data: from Millington et al., 2022

With Hall, Kasoar (In prep)

Drivers of change in agricultural fire

- Pasture fires decrease exponentially with increased economic growth, as land use intensifies



… A closing thought

- There are very real ethical questions regarding synthesis of global data on human-fire interactions
- But there are also ethical consequences to *not* synthesising such data

➢ *To the extent that global scientific models inform techno-political discourses around environmental change: livelihood fire users are currently excluded*